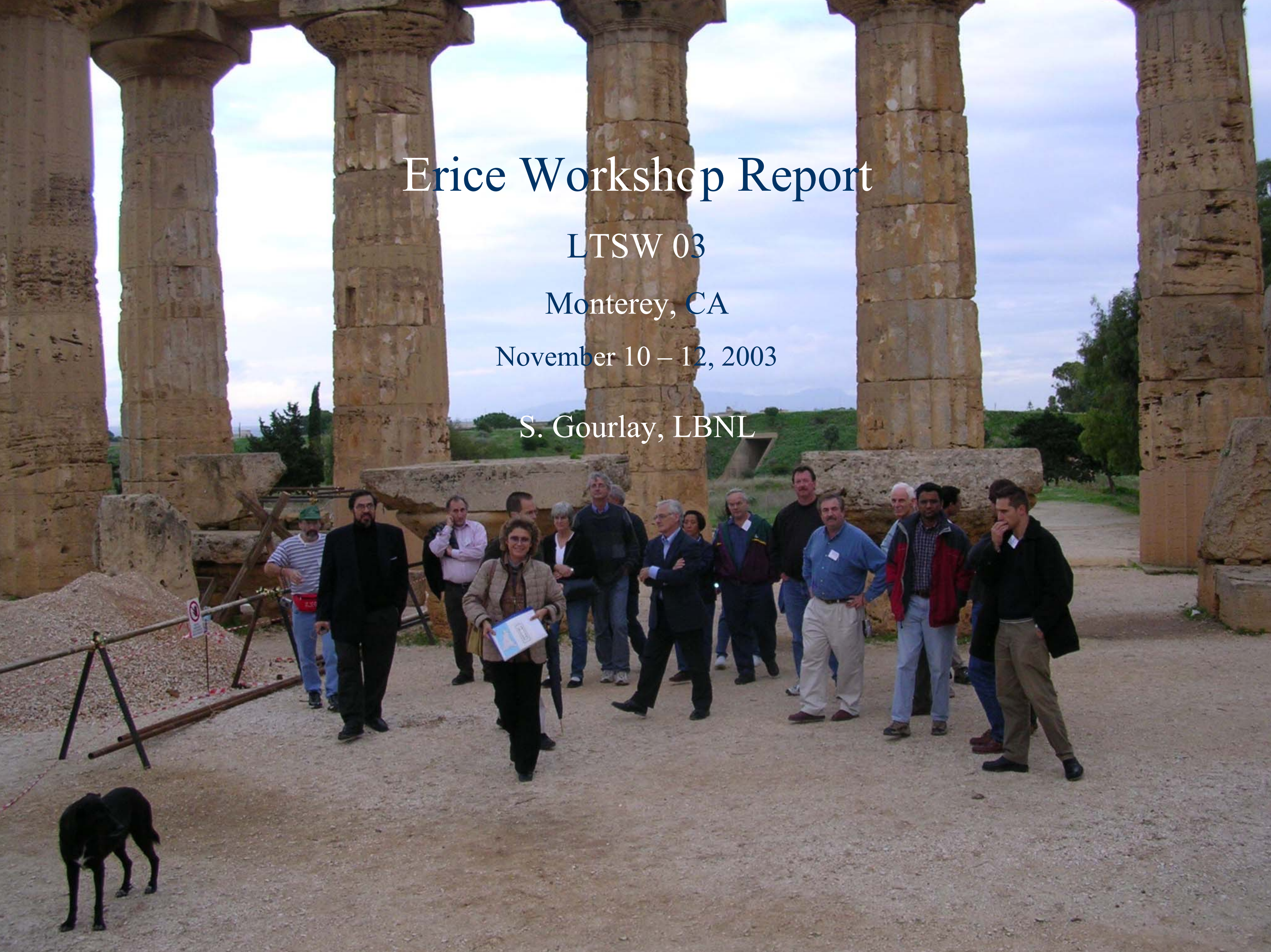
Erice Workshop Report

LTSW 03

Monterey, CA

November 10 – 12, 2003

S. Gourlay, LBNL



Workshop Goals

- Develop a coherent picture of current status
  - Define direction
- Identify issues and priorities for next Workshop on Advanced Accelerator Magnets (WAAM)
  - Get some work done between now and then

Working Groups

- Magnets at the limit of Nb_3Sn
  - Gian Luca Sabbi, LBNL, Chair
  - Davide Tomassini, CERN
  - Shlomo Caspi, LBNL
  - Michel Segreti, CEA/Saclay
  - Tom Taylor, CERN (ret.)
  - P. McIntyre, TAMU
- Materials
  - Ron Scanlan, LBNL, Chair
  - Bruce Strauss, DOE
  - Rene Flukiger, U. Geneva
  - Ettore Salpietro, EFDA
  - Seung Hong, OI-ST
- Superconducting Magnets in High Radiation Environments
  - Nikolai Mokhov, FNAL, Chair
  - Steve Gourlay, LBNL
  - Al Zeller, NSCL
  - Deepak Chichili, FNAL
  - S. van Sciver, NHMFL
- Fast Cycling Superconducting magnets
  - Arup Ghosh, BNL, Chair
  - Al McInturff, LBNL
  - Gebhard Moritz, GSI

Bill Barletta, Workshop Director

Magnets at the limit of Nb_3Sn

Goals

Concentrate on very high field magnets

(LHC upgrade is the most likely application in the "near" term)

Discussion Topics:

- Coil Design
- Mechanical support & assembly
- conductor, operating temperature
- aperture, field quality, dynamic range
- stored energy, inductance
- radiation issues

- *magnet cost*

Establish R&D targets?
(as for DOE conductor program)

Proposed Magnet R&D Targets

- Technology:

  #1: Bore field $\geq$ 18 T with $\geq$ 5 mm clear bore
  #2: Bore field $\geq$ 16 T with $\geq$ 30 mm clear bore (cold bore included)
  #3: Bore field $\geq$ 14 T with $\geq$ 3 m magnetic length

- Dipoles (B_0^{nom}=14 T, harmonics as measured at 10 mm physical radius):

  #4: All central harmonics $\leq$ 3 units at B_0^{nom}
  #5: All central harmonics $\leq$ 10 units from $0.1*B_0^{nom}$ to B_0^{nom} @ LHC R.R.

- Quadrupoles (G^{nom}=200 T/m, harm. as measured at 20 mm physical radius)

  #6: All central harmonics $\leq$ 3 units at G^{nom}

Materials

Main emphasis for HEP--reduce D_{eff}

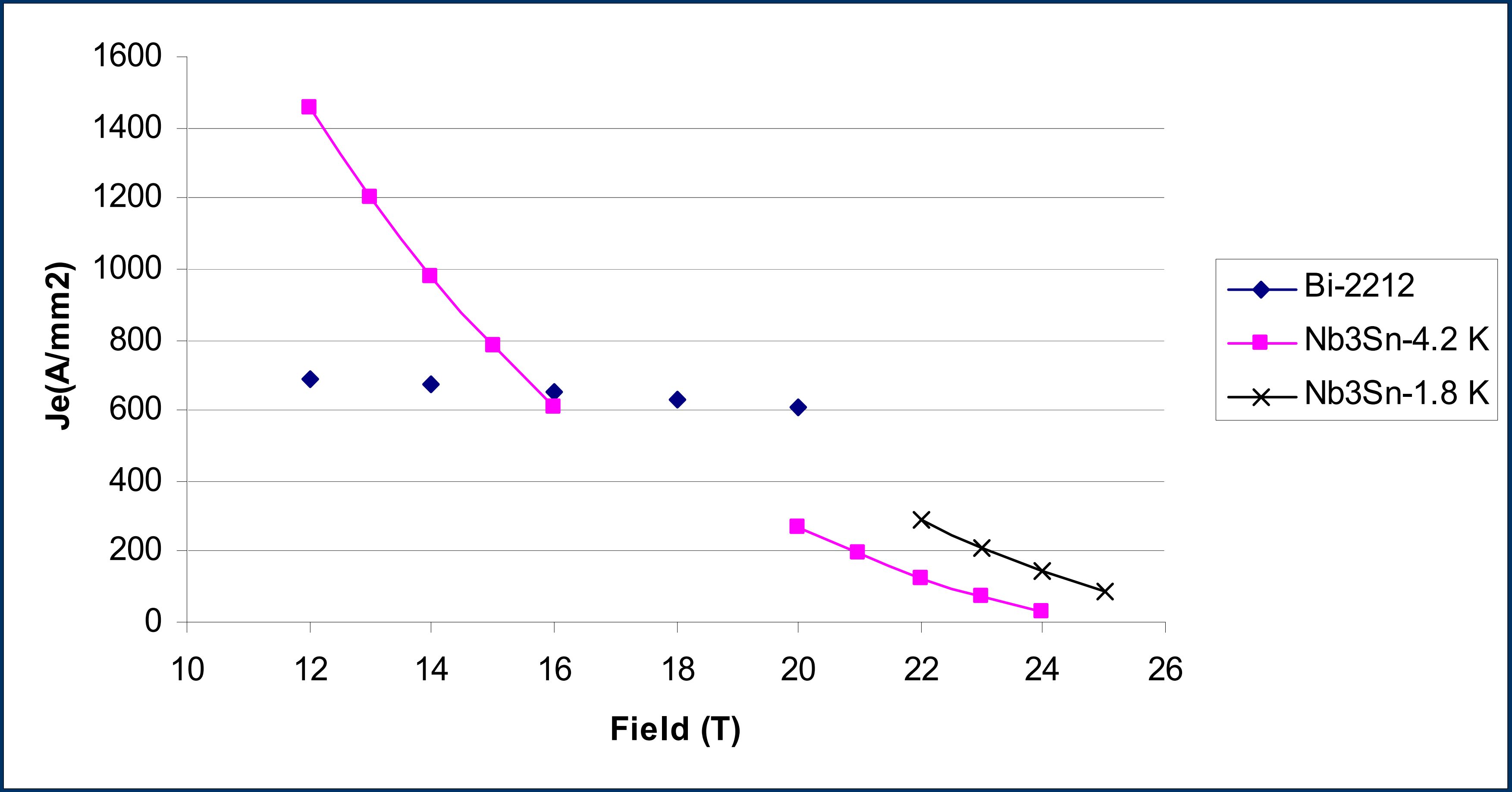
- Increase number of subelements (OST, OKAS, Supergenics)
- Use fins to subdivide subelements (OST, OKAS, Supergenics)
- PIT conductor fabrication (SMI, Supercon)

All three approaches can (in principle) produce D_{eff} = 40 microns, with J_c near 3000 A/mm^2.

Deff = 20 microns may be possible, but it is a big step, requiring more R&D

Another method to reduce magnetization at low fields--reduce low field J_c

Conductor Performance Comparison



Conductor Summary (Magnet WG)

- A 40% copper fraction may be feasible for RRP wires
  - Ic increase by +20% gives +0.5T in HD-1 at 4.2 K
  - Well worth pursuing, some risk (drawing, cabling)
- Ic measurements at 1.9 K in 16-18 (20) T range are needed
- Further R&D on keystoned cables required for cosθ designs
  - Some work already planned in connection with LARP
- Pay close attention to new conductors (e.g. with SM “technology” tests)
- Smaller filaments are not needed for LARP or present arc dipole R&D
  - Rather increase I_c, J_c, stress tolerance for near term R&D and applications
  - However, a statement from AP is required regarding LHC upgrade specs
  - Also, keep an eye on stability limits
- Much smaller filaments may ultimately be needed - develop in parallel ?

Nb_3Sn for ITER and HEP

- Many common issues

  --J_c vs strain behavior

  --Radiation damage limits for insulation (and conductor)

  --Scale up of production capacity (should reduce costs for both programs

- Conductor programs should be complementary and coordinated

SC Magnets in a High Radiation Environment

- Radiation issues for various machine configurations
  - LHC IR Upgrade
  - SLHC
  - VLHC
- Radiation dose limits for various materials
- Radiation heat-loads in SC magnets
- Cryogenic implications

Radiation Issues

- Quench stability (peak power density, heat transfer)
  - OK at LHC and SLHC with appropriate protection system
- Dynamic heat loads
  - OK at LHC (30 W/quad) and challenging at SLHC (3.5 kW in dipole-first)
- Radiation damage: 10-yr dose is 20 (LHC) to 50 MGy averaged over cable height
  - Neutron fluence seems to be not an issue 10^{16} to 4×10^{16} cm^{-2} over 10 years (3×10^{17} at SLHC Cosθ)
- Residual dose rates - Hands-on maintenance
    - OK at LHC and challenging at SLHC

General Radiation Dose Limits

Material	**Useful limit (MGy)**
Copper	$>10^4$
Iron, Stainless steel	$>>10^3$
Ceramics	$>10^3$
Organics	$\sim10^2$

(most sensitive properties)

Cryogenic Considerations

- Perspective from LHC point of view
  - Accelerator cryoplant: 4 x 18 kW = 72 kW @ 4.5 K
  - Beam screen requires 1.7 W/m between 4.6 and 20 K (1.7 W/m x 27 km = 45.9 kW)
  - Remaining ~ 26 kW mostly goes to 1.9 K cooling
  - 26 kW converts to ~ 11 kW @ 1.9 K due to lower thermodynamic efficiency
  - Average 1.9 K heat load on LHC accelerator magnets < 0.4 W/m
  - IR 110 W/4 quads (total = 440 W @ 1.9 K)

Cryogenics for Luminosity Upgrade

- Luminosity upgrade from 10^{34} to 10^{35} results in increase in beam screen heat load from 1.7 W/m to 15 W/m
  - Increase total screen load to 405 kW @ 4.6 to 20 K!
  - Impact on 1.9 K load on main ring dipoles (0.4 W/m to ~ 0.8 W/m) or ~ 22 kW @ 1.9 K
  - Can be handled by changes in cooling configuration
- Dipole-First
  - 3.5 kW x 4 dipoles = 14 kW (30 times LHC) at 1.9 K, 4.5 K, higher T?
- Options to consider
  - Operating magnets at higher T, but can they be cooled & stabilized?
  - Use of HTS would help with overall power requirements if they could operate ~ 20 K or higher.

Radiation Loads in SC Magnets

- Main ring magnets ~ total beam energy 0.35 GJ (LHC), 1.1 GJ (SLHC), 3.2 GJ (VLHC) and beam loss rate (electron clouds, collimation efficiency)

- IR magnets - upgrade energy, not luminosity

Rad WG Summary

- Generate table
  - Characterize various IR designs in terms of radiation environment
    - Peak energy deposition
    - Fluence
    - Dose
    - Cryo load
  - Define material properties and acceptable design criteria for given dose
- Survey of fusion program results
  - Identify relevant information (no duplication)
  - Identify areas for focus
    - Nb_3Sn behavior in LHC IR radiation field
      - Develop appropriate tests (magnetization measurements in lieu of direct Jc)
- Identify existing rad hard materials for incorporation into magnet programs
- Focus R&D on what is left

Fast Cycling SC Magnets

- Focus is on magnets for GSI IAF
  - SIS 100 ring cycling to 2 T at 4 T/s
  - SIS 200 ring cycling to 4T at 1 T/s
    - GSI-001 RHIC-style magnet
  - SIS 300 ring cycling to 6T at 1 T/s
- For cos-theta magnets
  - Minimize SC magnetization
    - Small filament diameter (2.5 micron)
    - Suppress proximity-coupling by using Cu-2.5% Mn matrix
  - Reduce eddy current magnetization
    - High resistive matric Cu-2.5% Mn
    - Small twist pitch, practical limit 5 X D
    - Jc > 2,500 A/mm2 at 5T

Fast Cycling SC Magnets

- SC magnets cycling at 1 – 4 T/s are quite feasible
- Develop strand with smaller filament size
  - 2.5 – 3.5 micron goal
  - Nb3Sn an option?
- Development of single tape "cored" cables
  - Eliminate R_c eddy current loss